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WALCH SCIENCE LITERACY SERIES

PHYSICS

David E. Newton

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Walch Science Literacy Series
Physics

by David E. Newton

illustrated by Carol Stutz

J. WESTON
WALCH
PUBLISHER
Portland, Maine

To the Student

How would you like to be one of the best thinkers in your school? Would you like to be able to put pieces of a problem together quickly and thoroughly in order to find a solution? Do you want to be able to spot flaws in weak arguments? Can you develop a strategy for setting up an experiment that will work to give you an answer to a problem?

Most students would like to be able to do all these things. But some of them are not as successful as they could be because they have not developed the skills—the "habits of mind"—of really good thinkers. In this program, you will learn some new thinking skills, and you will know when you are using them. You will become a more effective thinker and problem solver as you work through the science situations in this book.

Our best wishes for good thinking.

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Lesson 1

Jet Planes and Curveballs

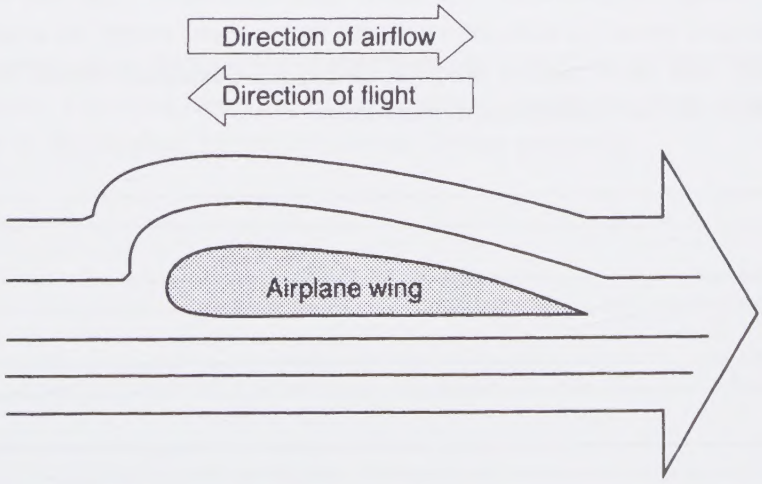
What do a jet airplane and a baseball pitcher's curveball have in common? They are both applications of **Bernoulli's principle**.

Bernoulli's principle is named after the Swiss mathematician Daniel Bernoulli (1700–1782). In about 1738, Bernoulli made an interesting discovery about the way fluids flow over surfaces. The term **fluid** can refer to either a gas or a liquid. Air and water are the most common fluids.

Bernoulli's principle says that the faster a fluid flows over a surface, the less pressure it exerts on that surface. To demonstrate Bernoulli's principle, hold two corners of a piece of paper in front of your face, just below your mouth. Then blow across the top of the paper. The paper rises, as if by magic. The magic is Bernoulli's principle. Blowing over the top of the paper forces air to flow rapidly over the upper surface of the paper. Air pressure on *top* of the paper is reduced. But air pressure on the *bottom* of the paper remains the same. Since the air pressure on the bottom of the paper is greater than the pressure on the top, the paper is pushed upward.

How could you modify this experiment using only a piece of paper to further test Bernoulli's principle? Try out your idea after obtaining your teacher's approval.

The value of Bernoulli's principle lies in the many applications it has. Jet airplanes, for example, have wings that are straight on the bottom and



curved on the top. As the jet moves forward, air rushes over the top of the wing faster than it does across the bottom. Pressure on top of the wing is less than on the bottom. Greater pressure below the wing pushes up on it and lifts the plane into the air.

A pitcher makes a baseball curve by giving it spin as the ball is released. As the ball travels toward the batter, the ball continues to spin. Air rushes past the ball faster on one side than on the other. Pressure is greater on one side of the ball than on the other. Thus, the ball is pushed away from a straight path. The ball curves.

One beauty of scientific laws like Bernoulli's principle is that they are generalizations. They refer not just to pieces of paper or jet airplane wings or baseballs but to many different kinds of phenomena. Another value is that they can be used to make predictions or develop **hypotheses**. What new ideas might a baseball pitcher have after learning about Bernoulli's principle? How would an airplane designer change the shape of an airplane wing as a result of knowing Bernoulli's principle? It's unlikely that many baseball pitchers think very much about this question. But for airplane designers, the question is a key part of their daily work.

Use reference sources such as library books and magazines or the Internet to find information to answer the following questions.

1. Who was Daniel Bernoulli? In the space provided, write a few interesting things about this man's life and work. Also tell one important event in science and one important event in world history that were taking place at the time Bernoulli lived. Write a report on the information you find.

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2. List other applications of Bernoulli's principle that you can find.

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3. Describe in detail how any one of the applications listed in question 2 works.

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4. Factors other than Bernoulli's principle are involved in the flight of an airplane. List and describe briefly other conditions that help an airplane to fly or that prevent it from flying properly.

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Lesson 2

Music: An Aid to Learning?

Background music has become a part of everyday life. Department stores and grocery stores, malls, office buildings, and even factories provide music to soothe us. People often don't bother to think about the music. They may not even realize it's there. It's just part of the setting, along with sculptures and plants and flowers.

For many students, background music is also important. They like to have a radio tuned to a classical program, a top-40 station, or heavy metal music. Some students feel that the setting for studying just isn't right without music in the background. Other students say they can't concentrate on their lessons without music playing.

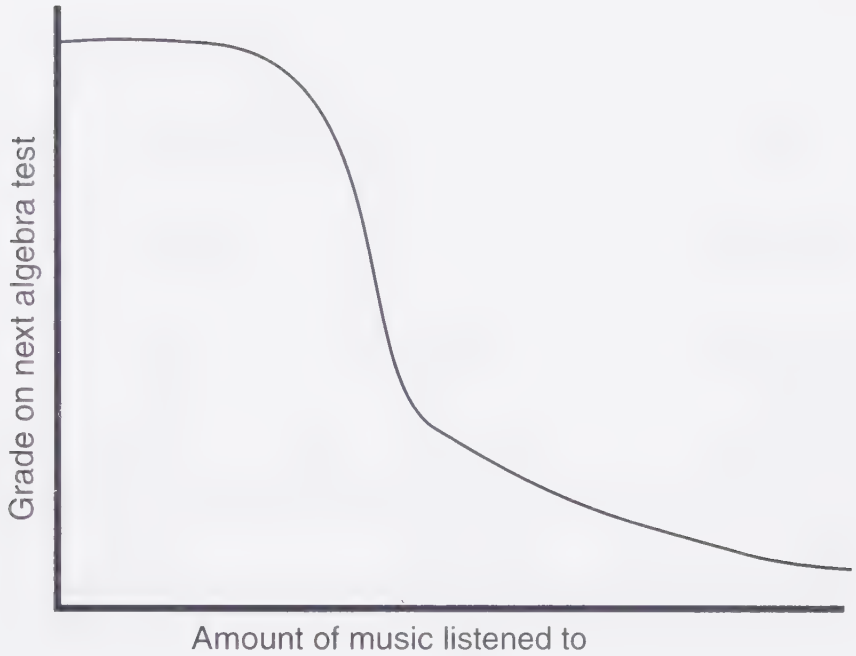
Some adults would disagree with those who like background music. They say that background music is distracting. The human mind can't concentrate well on two things at once, they argue. If part of your brain is listening to Beethoven or Bon Jovi, it isn't available for algebra or Russian history.

That's true, some people contend, even if you're not thinking about the music. You may think that your mind is entirely on the algebra book, but, subconsciously, you're singing along with Bon Jovi or Beethoven. Anything that affects your senses, they say, makes you study less efficiently.

This debate has inspired a number of scientific studies. Researchers have observed students working under two sets of conditions: one with background music, the other with total silence. They have measured how much students learn under each circumstance.

As with much scientific research, these studies often raise as many questions as they answer. Results obtained by one researcher may be questioned by a second researcher. Has the issue of background music and learning really been resolved? How do we know when *any* question has been answered by scientific research?

The results of one study on music and learning follow. The researcher's conclusions, based on these results, are that the greater the amount of noise present in a student's room, the less the student learns algebra.



The results of this study, as with many scientific studies, may be subject to different **interpretations.** Another scientist may look at the same results and come up with a different conclusion. How could this happen? The second scientist might find errors in the way the experiment was done. Perhaps an important factor was ignored in setting up the experiment, or the people used in the experiment were somehow different from average students. Or, there may be other ways to explain the results of the experiment.

1. List the two **variables** studied in this research.

_____

_____

2. State how the grades earned on the first algebra test following the experiment depended on the amount of music to which students listened while studying.

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3. What possible errors can you see in the way this experiment was conducted or reported?

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4. Based on what you know, list one or more **alternative explanations** that are different from those of the original researcher for the results obtained in this experiment.

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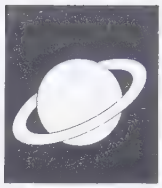

The Readsville Courier

Plans for Mars space station announced

The United States and Russia have announced a joint program to build a scientific research base on the surface of Mars by the year 2010, NASA Director Bonnie Phlyer announced today.

The base will house 35 scientists and staff at first and will be designed to carry out research on Mars' surface and interior and on other planets in the solar system.

The base is expected to cost $100 billion to build. Critics claim that the base is too expensive and say the money should be spent instead on social problems that need to be solved here on the earth.

Supporters argue that science must continually move forward, discovering more about the universe in which we live.

The Mars base proposal will be debated at next month's meeting of the federal government's Science Advisory Council.

Space research has long been the subject of debate in the United States. How important is it to send men and women into space to study the planets, our moon, the stars, and other objects? Can we justify spending money to launch space probes to fly by planets or to explore outer space?

The United States and other nations spend billions of dollars on such programs each year. Could this money be better spent? Certainly there are problems here on the earth that need our attention. Hunger, homelessness, and poverty are only three obvious examples. Some people argue that space research should be canceled and the money used to work on important problems in our everyday lives.

Differences of opinion about space research are part of a very old debate over the value of **basic research.** Basic research is research carried out primarily to learn about the natural world. Although some practical good may come from basic research, that is not its goal. The purpose of building a base on Mars is neither to improve transportation systems on the earth

nor to achieve any other practical goal. Such progress may occur as an accidental by-product of the Mars base. But it's not the main objective.

The Mars base would be paid for from your tax dollars. The most you can be certain about from this investment is that we will learn more about Mars, the other planets, and outer space. Is that good enough for you? Would you vote to approve funds for the Mars base?

Use reference sources such as library books and magazines or the Internet to find information to answer the following questions.

1. List three other examples of basic research.

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_____

2. Find out what is meant by *applied* research. Give an example.

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3. What connection is there, if any, between basic research and applied research?

4. What is technology? How does it differ from applied research?

Lesson 4
Watch Out!

Watch out for the car in front of you! That warning is always a good one and one that most driver education teachers repeat over and over again. Rear-end collisions are a common cause of damage to vehicles and of injuries to drivers and passengers.

The warning is necessary because of the time it takes to stop a moving automobile. That stopping time depends on two factors: the driver's **reaction time** and the time needed for car brakes to operate.

The term reaction time refers to the time it takes a person to see that he or she needs to apply the brakes, for that message to travel from the eyes to the brain and then to the foot, and for the brake pedal actually to be applied. Although the reaction time may be a fraction of a second or only a few seconds, a car continues to move during that time. The faster the car is moving, the farther it travels during the reaction time.

Even after the brake pedal has been applied, the car will continue moving. Brakes slow down a car; they do not stop it immediately.

The following chart shows the amount of time it takes to stop a car traveling at various speeds. The chart consists of *average* values only, however. It may take you more or less time to bring your car to a stop in case of an emergency.

Stopping Distance for a Car at Various Speeds

Speed	Reaction Time	Braking	Total
(mph)	Distance (feet)	Distance (feet)	Distance (feet)
10	11	9	20
20	22	23	45
30	33	45	78
40	44	81	125
50	55	133	188
60	66	206	272
70	77	304	381

1. What factors might affect an individual's reaction time?

_____

_____

_____

2. What factors affect the stopping time for a car?

_____

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3. Hypothesize a method by which you can determine a person's reaction time. Briefly describe your method.

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4. What factor is most important in determining the braking distance for a car?

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Lesson 5
Working Together

What's the biggest change that's taken place in science in the last hundred years? That's a difficult question, but one answer might be simple: size. At one time, an individual scientist working alone in his or her laboratory—with perhaps one or two assistants—using only simple equipment could make breakthrough discoveries in science. That's how Henri Becquerel and the Curies discovered radioactivity, how J. J. Thomson discovered the electron, and how Ernest Rutherford discovered the atomic nucleus.

But such discoveries are much less common today. Most scientific discoveries involve teams of scientists working in large laboratories equipped with large and expensive equipment. The discovery in 1983 of the subatomic particle known as the W boson, for example, was announced in a scientific paper with 135 physicists listed as authors.

No one can deny that brilliant new ideas are, and probably always will be, the product of individual minds—the minds of geniuses. A single name or pair of names will probably always be associated with the most important breakthroughs in science—discoveries for which Nobel Prizes are given. But most routine research and just-less-than-great discoveries today are the result of scientists working in groups.

One such discovery was that of conducting **plastic**, also known as conducting **polymer.** A **conductor** is a material that will carry an electric current. The term conducting plastic (or conducting polymer) would have shocked most scientists just a few decades ago. Plastics then were regarded as **insulators**, or nonconductors of electricity. In fact, plastics were and still are commonly used as coverings for electric wires and electrical appliances. The discoveries in the 1970's of plastics that can conduct the flow of electric current opened up a whole new field of technology.

Conducting polymers were first discovered accidentally in 1975 by Hideki Shirakawa at the Tokyo Institute of Technology. Shirakawa was trying to make a polymer known as polyacetylene from acetylene gas (used by welders). The procedure had actually been discovered 25 years earlier, but Shirakawa was interested in learning more about the polymer, originally described as a dark powder.

When Shirakawa gave instructions to one of his assistants, a foreign student who did not speak Japanese fluently, the student added too much **catalyst** to the reaction mixture. The resulting product turned out to be a new form of polyacetylene, a black metallic-looking film.

The conductive properties of the new form of polyacetylene were soon investigated by Alan MacDiarmid, professor of chemistry at the University of Pennsylvania. MacDiarmid learned about the material while visiting Shirakawa's laboratory. The two chemists worked together on polyacetylene. Eventually, they discovered that the addition of iodine to the polymer greatly increased its ability to conduct electricity.

Use reference sources, such as library books and magazines or the Internet, to find information to help answer the following questions.

1. What is a conductor of electric current? List some examples of conductors.

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2. What is an insulator? List some examples of insulators.

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3. How are conductors used in everyday applications?

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4. How are insulators used in everyday applications?

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5. How do the terms *plastic* and *polymer* differ from each other?

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Lesson 6

Astrology: Science or Nonscience?

Take these aspirin pills and they will cure your headache.

Wear this plastic device, and your teeth will become straight.

Wear this copper bracelet and the pain in your knees will go away.

Tell me your birth date and I'll tell you whether you'll become rich or poor.

Take these tablets, and they will kill the virus. The pills contain an herb used by the Chinese for centuries.

Tell me your family history and I'll tell you what the chances are of your baby's being born with sickle-cell anemia.

The world is full of advice. All kinds of people are ready and willing to offer ideas about our health and, in general, what we can expect in the future. You probably have heard offers like these in your own community. To whom should we listen when we need advice?

In some cultures, people go to their elders, the leaders of the tribe, or those who are specially gifted—the witch doctor or the medicine man. Such authorities have long-honored methods for solving problems and looking into the future—methods such as going into trances or reading natural signs.

In Western culture, most people tend to rely on scientific methods and scientific authorities to learn whatever they can about the future. Because of that fact, the culture contains a number of practices that appear to be scientific, perhaps even verge on the scientific, but cannot really be called scientific. Instead, they are labeled as **pseudosciences**, or false sciences.

Astrology is perhaps the best known of all pseudosciences. Astrology is the practice of predicting future events based on the position of stars and planets in the sky at some given time. At one time, most humans in Europe and Asia—including the world's greatest scientists—probably believed in some form of astrology. Today, astrology columns are still among the most widely read features in newspapers in every part of the United States. Are astrological predictions a dependable guide to future events? Is astrology a legitimate form of **science**?

For some time, astrologers attempted to demonstrate that, whether a science or not, their practice was a reliable and dependable method of predicting future events. Had they been successful in that effort, of course, astrology would now be qualified to be called a science.

1. Write your own one-sentence definition of science.

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2. Write a one-sentence definition of science taken from a dictionary.

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3. Write a one-sentence definition of science taken from any science textbook.

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4. Explain how the three previous definitions differ from each other.

5. What characteristic(s) must a statement have to have in order for it to be considered a scientific statement?

Lesson 7

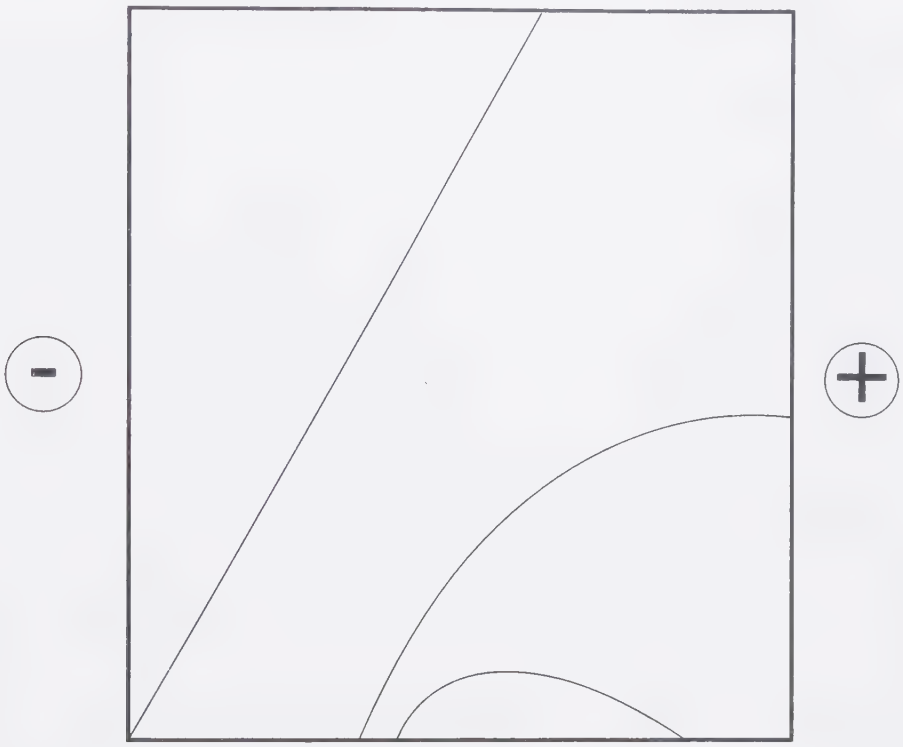
The Case of the Broken Platter

The kitchen floor was covered with broken glass. That was all that was left of Grandma Hough's beautiful old platter—that and a big ham bone, chewed clean of any meat or fat. What had happened? Your mother and dad were not expected home from work for another hour. And your brother was off at Little League practice. Only Spot was at home. And he was never allowed in the kitchen.

Not much of a mystery, is it? Spot may be a loyal dog and a good friend. But there doesn't seem to be much doubt as to how the broken platter and ham bone got on the kitchen floor. You might not be able to question the family pet, but from your **observations**, you can probably imagine what happened in the kitchen today.

The reason you can reconstruct the case of the broken platter is that you can infer what happened. **Inference** is the process of drawing conclusions about some event based solely on observations and logic. Inferences are an important technique for gathering information in science and in everyday life.

For example, the following diagram was collected from a satellite traveling 100 kilometers above the earth's surface. The three lines are tracks left by particles passing across a piece of photographic film in the satellite. The film was placed in an electric field that had a negative charge on the left side of the plate and a positive charge on the right side of the plate. What inferences can you make about the particles whose paths are recorded on this film?



1. What observations could be made in the case of the broken platter?

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2. What major inference can be drawn from these observations?

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3. What other inferences could you make from the same set of observations?

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4. How can you test any of the inferences you listed in questions 2 and 3?

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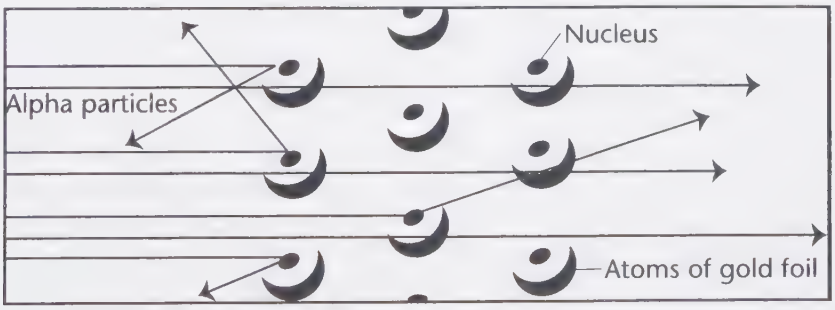
Harnessing Solar Energy

What does an atom look like? No one can answer that question with absolute certainty. Atoms are much too small to be seen with even the best microscopes. So, it is impossible simply to look at an atom or take its picture.

Yet, scientists believe that they know with a high degree of confidence what atoms look like. Chemistry and physics textbooks are filled with pictures of atoms. Scientists use these picture to guide their research. If atoms can't be seen, where do these pictures come from?

The answer is that pictures of atoms are not actual pictures, but **models.** A model is a representation of a real object. Most people are familiar with models. Many people, for example, build model cars or model airplanes as a hobby. Scientists use models for objects that are too far away, too large, or too small to be studied directly. Scientists also have pictures of stars and of the earth's interior, even though they have not seen either in person. Those pictures are models too.

How does a scientist build a model? The first step is to collect as much information as possible about the object to be modeled. To build a model of the gold atom, for example, scientists would first find out as much as possible about the element gold. Gold is made of gold atoms, and nothing else.



In one experiment, for example, a scientist fires high-energy **radiation**, such as X rays, at a thin piece of gold. Changes in the path taken by the radiation provide a hint about the structure of gold atoms. That hint is then used to build a model of the gold atom.

Next, the scientist builds the best possible model of a gold atom, based on all available information. The scientist draws the model on a piece of paper or makes a three-dimensional model of foam, Tinkertoys, wires, or other materials.

Then, the scientist makes predictions based on the model. The model gives the scientist a substitute for an actual picture of the atom. That substitute suggests tests and experiments that can be performed to refine and improve the model. As more and more tests are performed, the scientist gains more information and the model gets better and better.

Architects often make a model of a building before they begin construction of the real building. For example, they build a model of a solar house, a building in which the energy of sunlight, **solar energy**, is used to heat the house. To do this, they need to know as much as possible about solar heating. Then, they use that information to design and construct a model house.

1. List three objects or events for which a scientist might make a model. For each item you list, tell why a model is necessary or desirable.

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2. In what ways might a model differ from a real object or event?

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Lesson 9

Rapid Rails

MAGLEV: TRANSPORTATION FOR THE FUTURE

Proposal to the Six Cities City Council
21st-Century Transportation Company (TCTC)

Ladies and Gentlemen:

Six Cities has an opportunity to become part of the newest breakthrough in transportation technology in more than a hundred years. As you know, the state is currently developing plans for a new railway line to run through the Six Cities area. The line will be designed to carry trains that travel by magnetic levitation, called **maglev trains.**

The concept of maglev trains goes back to the late 1950's. But it remained a theoretical concept until recently, because there was no economical way to build magnets strong enough to carry railway trains. With the discovery of superconducting magnets, that problem has now been solved. It is now possible to build maglev trains that compete with both conventional trains and with the fastest commercial trains now operating anywhere in the world. Our representative, Fran Wiscaway, will now provide you with details on maglev train technology.

Nonscientists are often asked to make decisions about issues involving science and technology. Almost every day, you have to make choices about consumer products that contain chemicals—medicines, cosmetics, foods, cleaning agents, and so on. As a voter, you also have to make decisions about science-related issues. What kind of waste disposal plant should be built? How should a vacant parcel of land be put to use? What should be done to protect area wildlife?

How can a nonscientist make intelligent decisions on such issues? There are usually consultants and advisers who have expertise in the area of

science who are willing to give advice. But advice may not be unbiased. The advisers may have their own best interests at heart. Fortunately, nonscientists have lots of resources to which they can turn. Doing so ensures that they will get objective information on which to base a decision. What does the objective information have to say about maglev trains as a possible future means of transportation?

Use reference sources, such as library books, magazines, and the Internet, to find information to help you answer the following questions.

1. What is a magnetic field? Make a simple sketch that illustrates a magnetic field.

_____

_____

_____

Magnetic Field

2. What are the north and south poles of a magnet? How do these two kinds of poles affect each other?

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3. What does the term **superconductivity** mean?

_____

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4. Name three kinds of print sources from which you could obtain information about maglev trains.

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5. Name any kinds of nonprint sources from which you could obtain information about maglev trains.

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Lesson 10

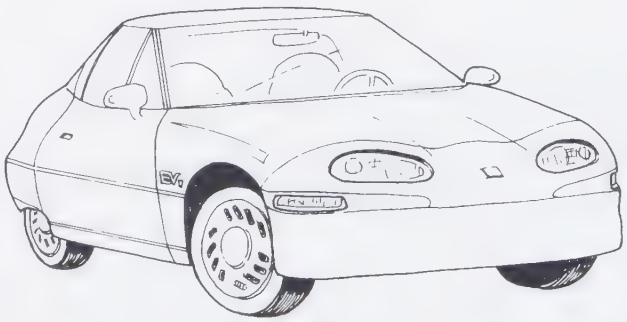
Plug-in Cars

A car for every student! Is that an appealing idea to you? When it comes time to leave for school, you simply unplug your car, back out of your garage, and cruise to school at a quiet 25 miles per hour. Your personal car makes almost no noise at all, and it produces no pollution. After school, you drive home again at a leisurely 25 mph, park in the garage, and plug your car back into its electrical outlet. The electricity recharges the batteries so the car will be ready for another drive tomorrow morning.

The personal car described here is an electric car. It runs not on gasoline, but on electrical power. The electrical power comes from batteries somewhat similar to the lead storage **battery** found in conventional cars. Most electric cars run at low speeds for a few hours and then have to be plugged into a source of electric current, like the plugs in your own home. The electric current recharges the batteries, and, a few hours later, the car is ready to run again.

Electric cars were once manufactured, like gasoline and diesel cars. But they never became popular and were not produced commercially for more than 50 years.

In 1997, the EV1 began rolling off a small assembly line in Lansing, Michigan. The electric cars were shipped to 26 car dealerships in Los Angeles and San Diego, California, and Phoenix and Tucson, Arizona. The two-passenger car can reach speeds of about 60 miles per hour and travel about 65 miles on a single battery charge.



Electric cars have a lot of potential for personal transportation. They travel quietly and produce no pollution, such as that given off by gasoline- and diesel-powered vehicles. Under the circumstances, why do you think electric-powered cars are not widely available? Do you see a broader use for such vehicles in the future?

1. Would you want to own an electric car? Why or why not?

_____

_____

2. Suppose you wanted to learn more about electric cars. What resources could you consult to get the information you need?

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3. What is a battery? What purpose does it serve in an electric car?

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4. What arguments can you think of against the development, manufacture, and sale of electric cars?

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5. What methods for powering vehicles other than gasoline, diesel oil, and electricity can you think of?

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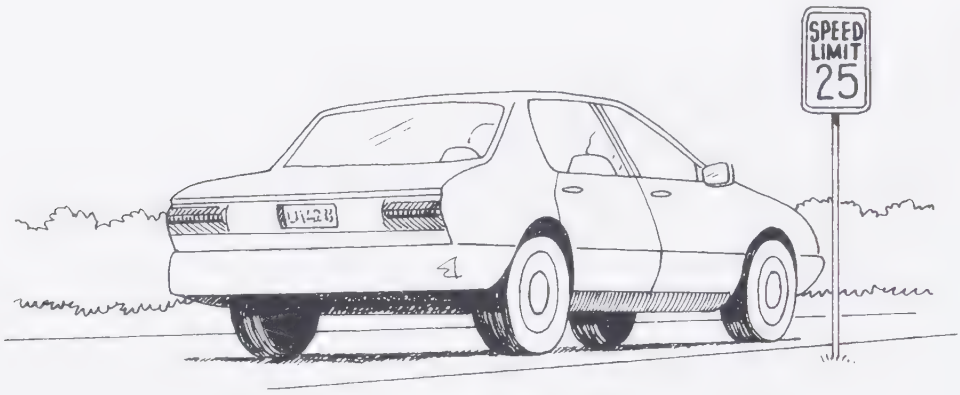
Lesson 11

How Fast Is Too Fast?

How fast should you drive a car? An easy question, perhaps—but one with many possible answers. Perhaps the speed limit in your neighborhood is 25 mph. But what if your sister is having a baby and has to be rushed to the hospital? In that case, it may be necessary to go 30 or 35 mph.



Or the speed limit on a freeway may limit you to 65 mph. But an accident on the highway shoulder would make it unwise to travel that fast. Other factors can make a difference, too. Perhaps you want to drive at the most economical speed—a speed at which your car uses gasoline most efficiently, which, therefore, saves you money.

The usual way to measure driving efficiency is in **miles per gallon** (mpg). The term miles per gallon refers to the number of miles you can drive a car on one gallon of gasoline. Miles per gallon vary depending on many factors, including make and year of a car, type of gasoline used, and driving speed.

As a budding young scientist, conduct an experiment on driving efficiency. Find a way to measure exactly how many miles you can drive on exactly one gallon of gasoline. Then, use your method to find out how many miles per gallon your 1994 Speedmobile gets driving at 15 mph, 25

mph, 35 mph, 45 mph, and 55 mph. The results you get for each condition are as follows: 10 mpg, 12 mpg, 14 mpg, 15 mpg, and 15 mpg.

Now the time has come to announce your results to an eagerly waiting world. How should you announce those results? You could, of course, just place into print the last two sentences of the previous paragraph. But as a budding young scientist, you know that better methods for reporting **data** are available. What are those methods?

1. What conditions other than driving speed might influence the number of miles per gallon obtained for any given gasoline in any given automobile?

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2. What advantages and disadvantages are there in reporting the results of an experiment in written English?

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3. Name three other ways in which the data collected in the driving-efficiency experiment can be presented.

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4. What advantages do each of the methods you named in question 3 have over the use of written English sentences?

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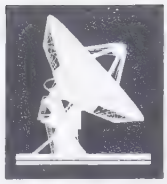


Lesson 12

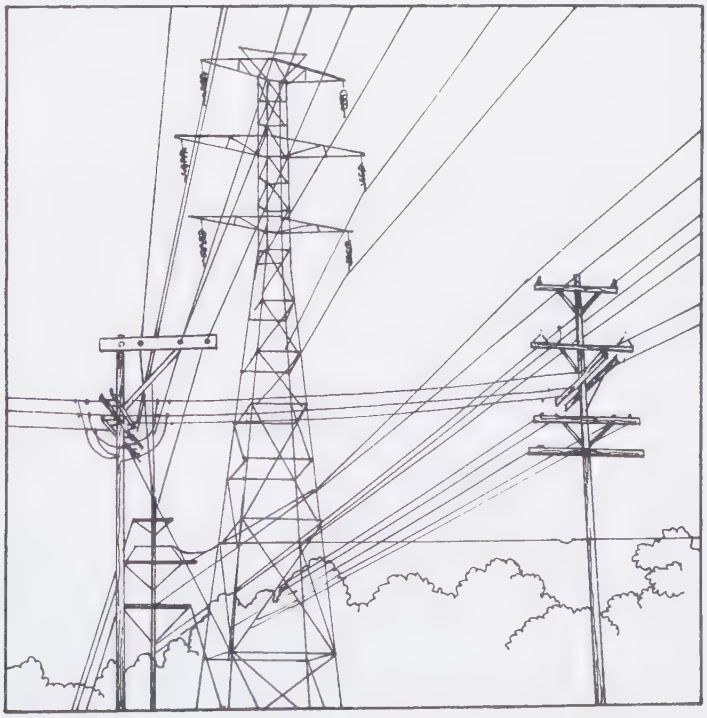
Is TV Watching Dangerous?

How dangerous is it to watch television? Some experts believe that TV watching can lead to violent behavior because of the content of TV programs. But that's not the point of this question. How dangerous is TV viewing to your physical health? That question has also been asked, because of the way television sets operate.

The picture on a television set is produced when a beam of **electrons** is projected onto the television screen by an electron gun at the back of the set. The electrons cause chemicals on the TV screen to glow, producing the pictures you see.

Some of these electrons pass through the screen and out of the set. If you sit very close to the set, some of the electrons may strike your body. Will those electrons cause damage to your body?

This question is only one small part of the larger question of possible health effects caused by **electromagnetic radiation.** Anytime a flow of electrons occurs, a **magnetic field** is also created. The combination of electron flow and magnetic field is known as an **electromagnetic** (EM) **field.**



EM fields exist around the electron beam created inside your television picture tube, around the electrical wires in your home, and around the transmission wires that carry electric current from an electric power generating plant to your community and to your home. The strength of the EM field varies depending on the strength of the electron flow, or electrical current. The strength of the EM field around an electric wire in your home is many times less than the strength of the EM field around a transmission wire.

Some forms of EM radiation, such as X rays and gamma rays, are known to cause health effects in humans, other animals, and plants. Are humans at risk because they sit too close to a television set, sleep under an electric blanket, use too many electrical appliances in their home, or live too close to electric transmission wires? How would a scientist go about finding the answers to questions such as these?

1. What kinds of experiments could be designed to decide the dangers of EM radiation to plants and animals?

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2. Could the experiments listed in question 1 be used with humans? Why or why not?

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3. How could the effects of EM fields on humans be studied?

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4. List as many sources of EM radiation to which humans might be exposed as you can think of. Do you think all sources of exposure should be of equal concern? Why or why not?

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Lesson 13
Experts Speak

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Record of testimony presented before the Sunny Valley City Council by Dr. Lucy B. Wright, People for the Environment

Council Members:

I ask you to deny a building permit to the Glow-Brite Power Company for construction of a new nuclear power plant on the outskirts of your town. Nuclear power was once a promising source of energy in the United States. But no one any longer considers it to be that. No nuclear power plant has been built in the United States for over a decade. The reason is the dangers of radiation emitted by the plant are too great. People living less than a mile from the plant can receive levels of radiation that can cause cancer or even death. People living farther away are also at risk. Women may experience a higher rate of miscarriages, and babies may suffer from genetic disorders. Let's keep the environment 100 percent free of radiation. Other sources of power are available with much less risk to human health.

==========

Nuclear power plants have long been the subject of serious debate in the United States. When plans are announced to build such plants, people on both sides of the issue argue vigorously. Statements like those of Dr. Wright (about an imaginary case) are common.

In many cases, statements are made as facts about the benefits and risks of nuclear power. How is the average citizen to judge these statements? Are they really **facts** or simply **opinions**? Should we believe everything Dr. Wright says? or only some of what she says? or none of it? How do we know whether to trust Dr. Wright at all?

These questions arise often in discussions of issues involving science and technology, issues such as biotechnology, global climate change, and the like. But they also arise in other areas, such as the political, social, economic, and ethical choices that people have to make in their everyday lives.

1. What is a fact?

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2. What is an opinion?

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3. How can you tell the difference between a fact and an opinion?

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4. What information would you want to know about Dr. Wright in order to decide how much confidence to give her comments?

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5. What resources could you use to learn more about the topic of nuclear power plants?

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Lesson 14

Bubbleology

Who doesn't love a game? It could be bridge or Go Fish, stickball or baseball, one-on-one or professional basketball. Games are fun.

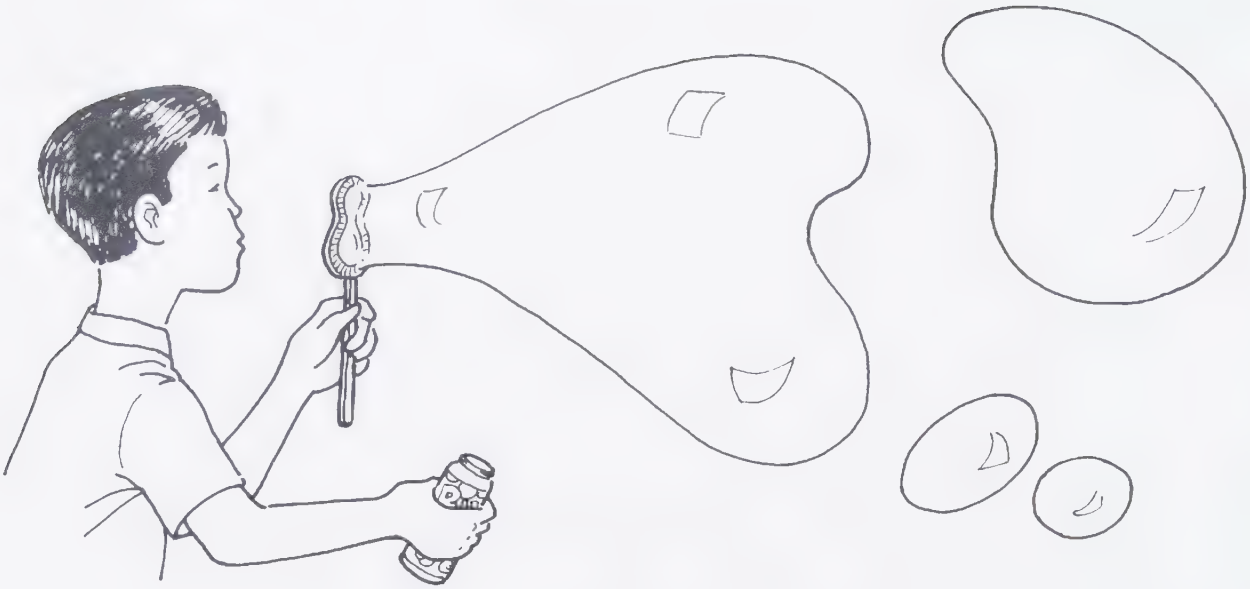
But games are often more than just fun. They are usually forms of competition in which the better person or team wins. For many people, games are not just a way to relax and enjoy themselves. They are a way to make a living by being better than the competition. You may play basketball just for the fun of it, but Michael Jordan plays basketball because he can earn tens of millions of dollars by doing so.

How do people who play games get better at what they do? One answer, of course, is to practice. But another answer is to find new and different ways of doing things: a new way to throw a curveball, a new way to set a pick, a new way to twist the body in a dive.

Trying out new ideas is an important part of science, too. The process is called making a **hypothesis.** A hypothesis is a guess as to how something might happen in the future. What will happen if we change the shape of a rocket ship as it flies through space? What will happen if we change the shape of a football when it's thrown in a forward pass?

Hypotheses are at the core of scientific progress, just as they are essential to improving game skills. However, making a hypothesis isn't the end of the process. You then test your hypothesis by using **experiments** and/or observations. You may find out your hypothesis was right, or you may find out it was wrong.

For example, consider bubbleology, the science of bubbles. Does soapy water make longer-lasting bubbles than fresh water? What kind of bubble solution allows you to make the biggest bubbles? What kind of bubble wand makes the biggest bubbles? All these questions about bubbles suggest hypotheses you could make. You could then devise a way to test your hypotheses. Who knows, you could become a bubbleology expert.



1. Where do scientists and game players get their hypotheses?

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2. How does a person know if a hypothesis is correct or not?

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3. What differences are there, if any, between the way scientists make hypotheses and the way game players make hypotheses?

4. Are game players likely to tell other game players about their hypotheses? Why or why not?

5. Are scientists likely to tell other scientists about their hypotheses? What are some reasons they might? What are some reasons they might not?

Lesson 15

How to End a Headache

AMFLAX
will relieve your headache in 30 minutes

Only 45 minutes and your headache is gone

PAIN-GONE!
Relief from headache pain

Which headache remedy should you buy? Lots of choices are available, but which one is best for you?

One way to answer that question is to do an experiment. Every time you get a headache, you could take a different remedy. After many trials, you might be able to decide which remedy you should choose in the future.

Drugmakers often conduct experiments like this one for you. The main difference is that they use hundreds or thousands of people for their research. They can find out how long it takes compound A to relieve a headache, how long it takes compound B, how long it takes compound C, and so on. Then they can decide which compound to use as their headache product.

Imagine what it's like to review the results of research on four different compounds with 2500 people. What's the best way to analyze all the data? You could say patient 1's headache was gone in 40 minutes with compound A, patient 2's headache was gone in 35 minutes with compound B, patient 3's headache was gone in 45 minutes with compound C, and so on.

A much more efficient way to analyze the data would be to make a chart or a **table.** A chart or a table is simply a way of displaying **quantitative (numerical) information** in an organized way. For example, the results of the headache research described might be presented as follows.

HEADACHE RESEARCH	
Compound	**Time Needed to Relieve a Headache**
A	45.8 minutes
B	31.2 minutes
C	52.9 minutes
D	40.7 minutes

A person can look at this table and, in almost no time at all, decide which compound works fastest for headaches. That's the major reason for making tables of data. Patterns and trends in data can be recognized easily and quickly. Then decisions can be made more efficiently.

1. In the headache remedy experiment described, what other information could have been collected in the research?

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2. How could the additional information you listed in question 1 have been displayed in a table?

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3. What other ways than in a chart can you think of for expressing quantitative data?

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4. What advantages or disadvantages do these other methods have compared to the use of a chart to display data?

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Lesson 16

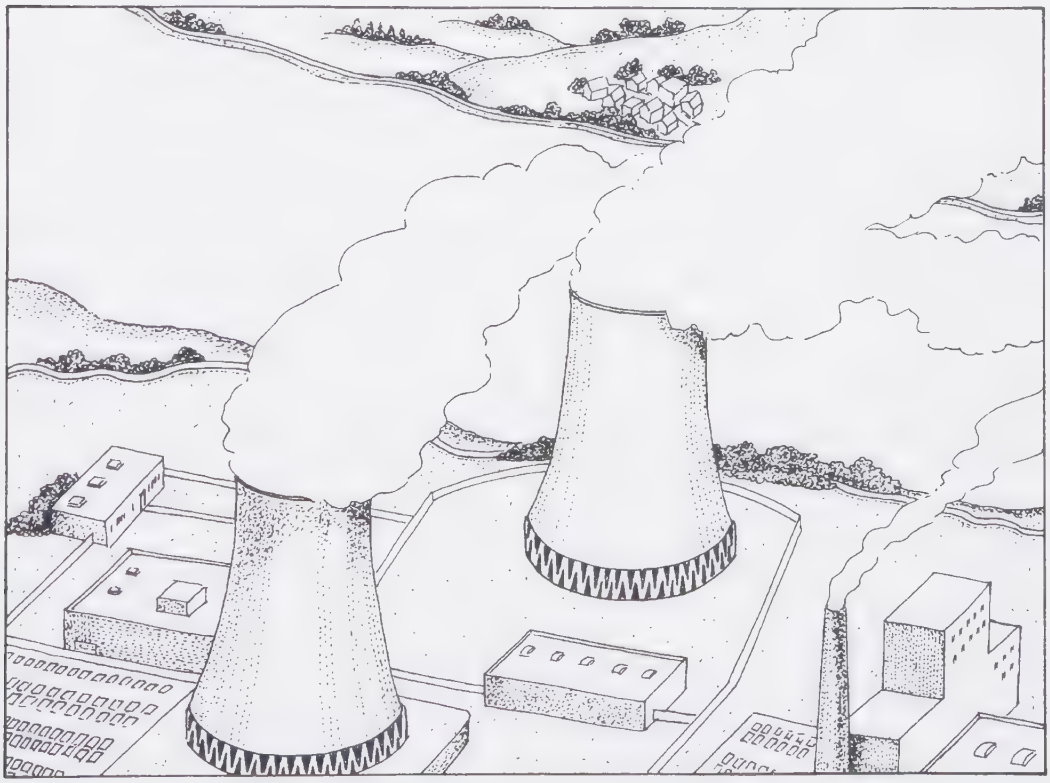
The Debate over Nuclear Power

"It's the greatest accomplishment in the history of humankind."

"It's the most dangerous discovery ever made by scientists."

These two statements are typical of the kinds of opinions people have about nuclear power. Which of the statements do you agree with?

The discovery of nuclear energy in the 1940's had two quite different results. The first use of nuclear energy was in the development of atomic weapons: the atomic bomb and the hydrogen bomb. But scientists who worked on these horribly destructive weapons knew that nuclear energy could also benefit humans. It could be the most valuable source of energy ever invented.



The first electrical power plant to operate on nuclear energy was the Shippingport Nuclear Reactor, constructed in Shippingport, Pennsylvania, in 1957. During the 25 years that followed, more than 70 more **nuclear power plants** were built in the United States. Energy companies were convinced that nuclear power would be an important factor in solving the nation's energy needs in the future.

But the dangers of nuclear plants soon became apparent. Building all of the safety devices needed to prevent accidents at a nuclear plant became enormously expensive. The general public worried more and more about the dangers of a terrible accident that would cause destruction such as that produced by nuclear weapons. Legislators demanded stronger and stronger safety systems. The cost of building nuclear power plants got so high that the electric companies changed their minds. They began to turn their backs on nuclear power. No new nuclear power plants have been built in the United States in over a decade.

Is nuclear energy really too dangerous to use as a source of electric power? Are the risks of nuclear power really so great that we can no longer think of building such structures? Or have critics exaggerated the dangers of nuclear energy beyond a point that is really justified? It's your turn to decide how you feel about these questions.

Use reference sources, such as library books and magazines or the Internet, to find information to answer the following questions

1. Nuclear power is released as the result of a reaction known as nuclear fission. Explain what happens in a **nuclear fission reaction**.

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2. What are the products of any nuclear fission reaction?

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3. Explain the steps by which a nuclear fission reaction can be used to generate electricity.

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4. List at least two environmental threats posed by nuclear power plants.

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5. List at least two arguments in favor of building nuclear power plants for the generation of electricity.

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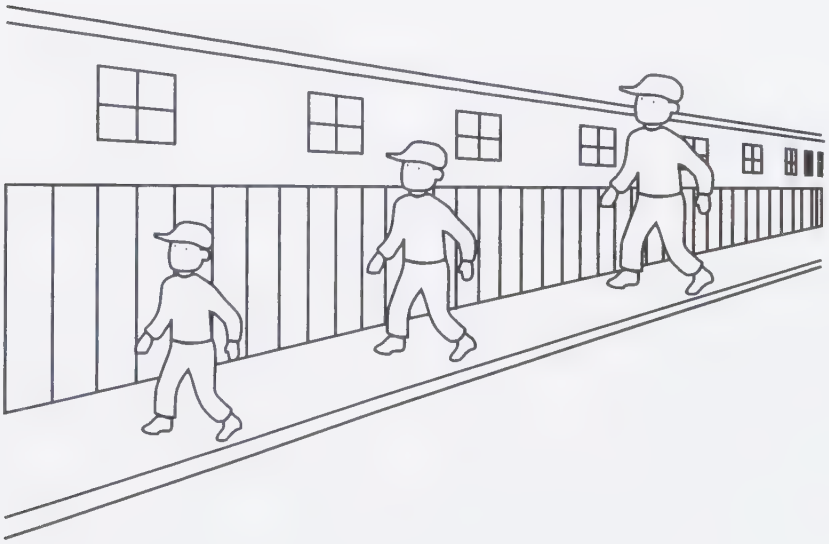
Lesson 17

Seeing Is Believing

"Seeing is believing" could be taken as a sacred rule in science. Everything that scientists know about the natural world is based on what they observe. Observations may come from any one of the five senses: sight, hearing, smell, touch, or taste. They also may come from using the unaided senses or by using a special instrument to improve those senses. But, at its most basic level, all scientific truth comes from what we learn about nature firsthand.

Yet, the commonly quoted phrase "Seeing is believing" may not be as obvious as it seems. Look at the following drawing. What do your eyes tell you about this drawing? Which of the three figures in the drawing is the tallest?



In fact, our senses are fooled more commonly than we might like to think. If you actually measure the three figures in the drawing, what do you find out?

Indeed, one reason that **measurement** is so important in science is that our senses do often betray us. In some cases, as with the previous drawing, our eyes become confused. Confusing figures of this kind are known as **optical illusions**—reports made by our eyes to our brain that are not correct.

But other senses can be fooled, also. Two people listening to the same sound may disagree as to the pitch or loudness of the sound. Two people feeling the same container of water may disagree as to whether the water is warm or cool. The only way to get accurate data about the physical world is to use a variety of measuring techniques and devices.

1. What is there about the previous drawing that makes the three figures seem to have different heights?

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2. List other examples of ways in which our senses may not report accurate observations about the natural world.

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3. Name some measuring instruments that are commonly used in getting accurate observations about the natural world.

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4. Are measured observations ever wrong? Why or why not?

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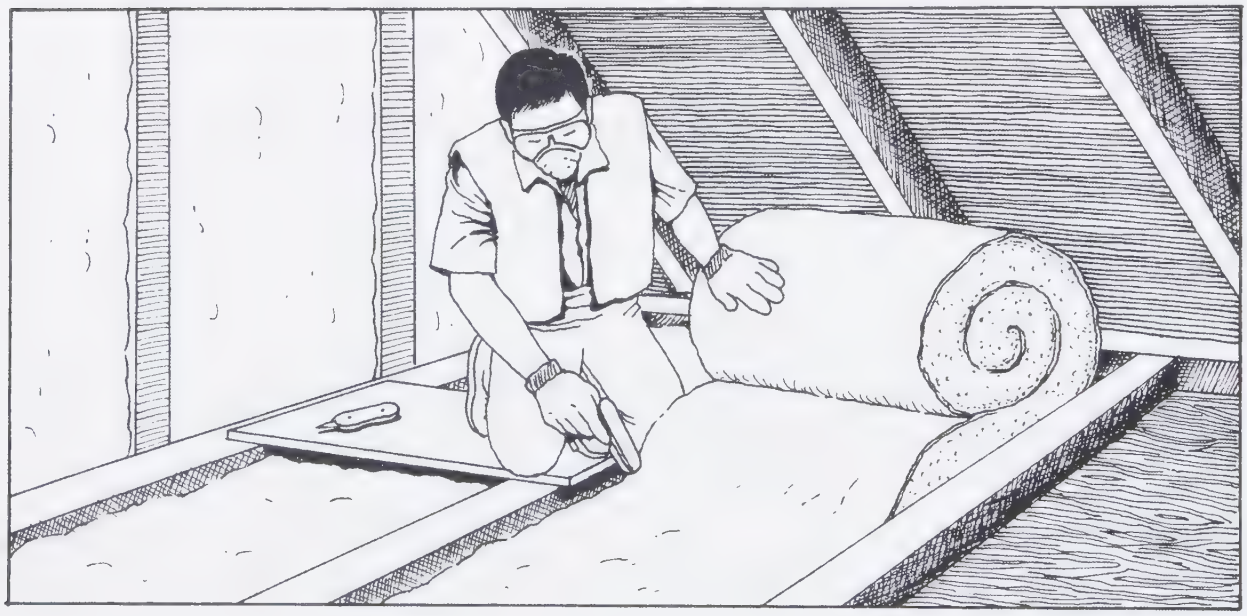
Lesson 18

How R You at Saving Energy?

The house Dave lives in was built in 1896. How does he know that fact? Easy. When they remodeled the dining room, the family removed the interior walls to the bare studs. Between the studs, they found newspapers published in 1896. They believe the newspapers were put into the walls when the house was first built.

So that may be a good way to date the age of Dave's house. But why would people put newspapers in the walls of their house? The answer to that question tells us something that humans have known for many centuries. The buildings we live in lose heat in the winter and gain heat in the summer. If we want to build a comfortable house, we probably need to insulate the house.



To insulate a house means to add materials that prevent heat from escaping in the winter and that prevent heat from entering the house in the summer. Paper is a good **insulator** of heat. You may have heard of homeless people who keep themselves warm by stuffing newspapers inside their shirts and pants. The newspapers prevent their body heat from escaping to the outside air.

Are newspapers the best possible way to insulate a house? Today, you can buy many kinds of insulating materials to use in your house. Is there a way to find out which materials are better than others?

Use reference sources, such as dictionaries and library books, to find information to help you answer the following questions.

1. Write a scientific definition of the word *insulator.*

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2. Based on what you know, name some materials that are good insulators of heat.

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3. A conductor is the opposite of an insulator. Write a scientific definition of the word **conductor**.

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4. Based on what you know, list some materials that are good conductors of heat.

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5. The ability of commercial insulation to prevent heat loss is often graded by means of an **R-value**. What does the R-value stand for on insulating materials?

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Lesson 19

Taking Apart Sunlight

Choosing a new pair of sunglasses can be a difficult decision. One important consideration, of course, is how the glasses look. Styles change often, and most people want to make sure that the glasses they are wearing are consistent with the current style.

But sunglasses are, after all, intended primarily to make it easier to see things on a bright, sunny day. How do sunglasses make that possible? The lenses in sunglasses make viewing easier in at least two ways. First, most sunglasses contain lenses that are made of dark glass. Dark lenses are dark because they do not allow light to pass through them. The glass of which they are made contains materials that absorb sunlight, preventing it from entering the wearer's eyes.

In other kinds of sunglasses, the lenses are made of **polarizing** (or polaroid) **material.** Polarizing materials also remove a certain amount of sunlight, but in a different way from the way dark glasses do.

Sunlight consists of light waves that travel through space, vibrating in every possible direction. If you could see a single bundle of light rays, for example, you would notice that some are vibrating up and down, others back and forth, and still others in every other possible direction. Polarizing

materials consist of crystals that let light that is vibrating in only certain directions to pass through. Light vibrating in other directions is blocked out. As a result, the total light passing through the glasses and reaching the wearer's eyes is reduced.

If you have ever worn polaroid sunglasses, you may have noticed some strange effects. Objects may look different depending on the direction from which you look at them. Why do you think this is? Can you think of some experiments you could conduct to find out?

Use reference sources, such as library books and magazines or the Internet, to find information to answer the following questions.

1. What is light?

_____

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2. Explain the mechanism by which light is transmitted.

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3. Based on your answer to question 2, hypothesize a method by which light can be polarized.

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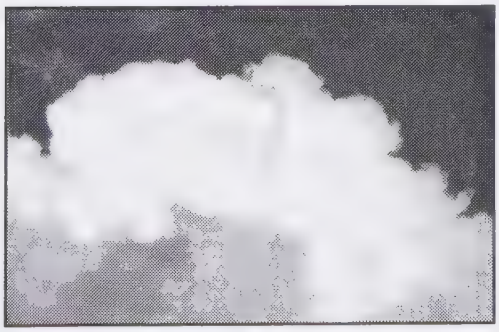
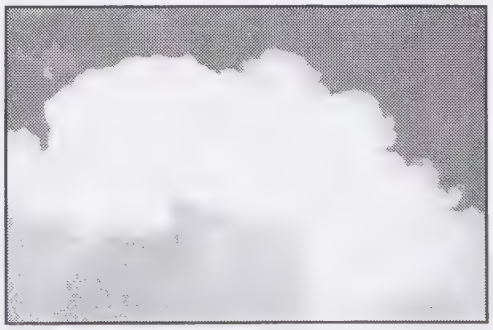
4. Do you think that any other form of energy besides light can be polarized? Why or why not?

5. The photo on the left was shot with a polarizing filter. The photo on the right was not. What effect did the filter have on the reflections? How did it do this?





Lesson 20

Tomorrow's Technologies

Imagine a television set only two inches thick that can be hung on the wall like a picture. How would that invention affect your future?

What about a high-fidelity loudspeaker less than 1/32 inch thick? or a telephone that can be connected to a television set to provide pictures of the person with whom you are talking? or an automobile safety system that will shock anyone trying to break into your car with a powerful electronic pulse? or a smart credit card that can be used as a checkbook, a savings account passbook, or an ATM card?

Most of us have come to expect marvelous advances as the result of scientific research. Still, when we hear about some of the inventions that are being studied, it is easy to be surprised and shocked. Yet, how many people living in the early 1900's would have imagined the existence of helicopters, computers, hand-held calculators, artificial fibers and dyes, wonder medicines, and dozens of other breakthroughs in **technology?**

Yet, every advance in technology poses certain questions that go beyond the invention itself. What safety requirements do you have to think about when you use a smart card like the one previously described? What questions are likely to arise when picture telephones become widely available? Are the problems created by some inventions so significant that we might want to put those inventions on hold until the problems are resolved?

One way to deal with new technology is simply to accept it with all the advantages and disadvantages it may have. A better way to handle such technology is probably to understand as well as we can how it works, what kinds of new opportunities it will present to humans, and how we can make the best possible use of those opportunities.

1. What does the term *technology* mean?

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2. List some examples of technology that have been invented within the past 50 years.

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3. Name some social, political, ethical, or economic problems that may have developed as a result of the inventions you listed in question 2.

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4. Describe some kinds of technology that you would like to see invented in the next 50 years. In each case, tell how likely you think it is that each kind of technology will actually be invented.

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Glossary

aerodynamics	science that deals with forces exerted by air or other gases in motion
alternative explanations	different ways to probe for errors in original work
astrology	pseudoscience practice of trying to predict future events based on the position of the stars and planets in the sky at any given time
basic research	investigations or research carried out to learn about the natural world without any specific application in mind
battery	set of two or more electric cells connected together for the production of electric current
Bernoulli's principle	fundamental generalization about fluid dynamics, stating that as the velocity of a gas increases, the pressure it exerts decreases
catalyst	substance that causes or speeds up a chemical reaction
chart	graphic representation of data
conduction	transfer of energy through matter by direct contact of particles
conductor	material that allows heat or electrons to move easily through it
convection	transfer of energy through matter by the movement of a gas or liquid
data	recorded facts from which conclusions can be drawn
electromagnet	temporary magnet that forms when an electric current is passed through a wire coiled around iron
electromagnetic field	area in which exists a combination of electron flow and a magnetic field
electromagnetic radiation	waves of energy traveling through space as a result of changing electricity and magnetism
electron	particle having a negative electric charge usually moving around the nucleus of an atom

experiment	trial or test to find out or discover something unknown or to verify a hypothesis
fact	something known to be true
fluid	any material that can flow, such as a liquid or a gas
graph	diagram in which a system of one or more curves, lines, or points shows how one quantity depends on another
hydrodynamics	branch of science dealing with the forces exerted by water and other liquids in motion
hypotheses	possible explanations or reasonable guesses about how or why an event happens
inference	conclusion arrived at by applying logic to known facts and observations
internal combustion engine	engine in which power is produced by the burning of a mixture of fuel and air inside the engine itself, usually inside cylinders
interpretation	a person's idea on the meaning of facts and observations
insulator	material through which electricity cannot flow
maglev train	train that runs on magnetic forces instead of fuels
magnetic field	area around a magnet in which an object feels a magnetic force
magnetic pole	one of the two ends of a piece of magnetic material where the magnetic forces are strongest
measurement	a size, quantity, or amount of something determined by measuring
miles per gallon	number of miles a vehicle can travel on one gallon of fuel
model	representation of how something looks or works
nuclear fission reaction	the splitting of an atom's nucleus into two nuclei having smaller masses, accompanied by a release of energy
observation	collection of data or information by using one's senses with or without the aid of instruments
opinion	what a person thinks about something
optical illusion	image that appears to be other than what it actually is

plastic	large group of synthetic organic compounds which can be heated and molded into various shapes
polarized light	light in which light waves vibrate in the same direction instead of being scattered
polarizing material	materials consisting of crystals that let light that is vibrating in only certain directions pass through
polymer	huge molecule made of many smaller organic molecules linked together; a substance composed of these large molecules
pseudoscience	a discipline that some people presume to be a science but is not; a false science
quantitative information	numerical data
radiation	energy emitted by a radioactive substance as a result of atomic decay
reaction time	the time it takes for a person to see the need for action and for the brain to send signals to various body parts for the correct response
R-value	indication of a material's ability to insulate; the higher the number (value of R), the more effective it is as an insulator
scatter graph	cloudlike sketch of electron probabilities
science	study of the natural world and the knowledge gathered from this study
scientific fact	something known to be true based on observation and testing
solar energy	energy from the sun
superconductivity	the conducting of an electrical current without resistance
table	information in a brief, tabulated form
technology	the use of scientific knowledge to improve the quality of human life
variable	the quantity that is changed or varied in a controlled experiment

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David E. Newton

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